Incentives, competencies and knowledge: evidence from France and theoretical integration

Incentivos, competências e conhecimento: evidência na França e integração teórica

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ABSTRACT

This paper examines the knowledge creation, sharing and transferring process within manufacturing firms in an innovation perspective. First, using French data set, we aim at studying the complementarities between human resource management and knowledge management practices (henceforth, HRM and KM), and their impact on innovation. Organizational diversity of the firms is showed. Three clusters or bundles of organizational practices are identified as “HRM and KM practices systems”. They characterized respectively (i) traditional firms at the work organization concerned; (ii) firms using incentives personnel practices and (iii) learning firms using, added to incentives, knowledge management practices. They correspond to theoretical organizational models including modern organizational forms, based on incentives to develop competencies and knowledge, without forgetting inspired tayloring firms. Empirical results permit to conclude that HRM and KM practices bundles have significant and posi-

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tive impact on innovation performance, while marginal changes in individual practices have little effect. Second, in order to confirm these complementarities, we focus on four specific practices mainly used by firms: team, incentives, training and knowledge management. We use a new testing procedure, based on the supermodularity concept, for complementarity and substitutability in case there are multiple organizational practices that affect innovative performance. This procedure is based on multiple inequality restriction. Our results suggest that firms use some practices in a joint way and systematically, and account for existing synergies. The result supports the notion that knowledge management is more effective if accompanied by team organization and associated incentives. This implies to construct a more comprehensive integration between agency and incentives theories and theories based on competencies and knowledge.

**Keywords:** Knowledge Management; Human Resource Practices; Innovation; Complementarity; Supermodularity.

**Resumo**
Este artigo examina a criação do conhecimento, bem como a partilha e a transferência de processos em firmas de manufatura na perspectiva da inovação. Primeiramente, usando dados franceses, mostra a complementariedade entre a gerência de recursos humanos e as práticas de gerência do conhecimento (HRM e KM), e seu impacto na inovação. Expõe a diversidade organizacional das firmas. Três conjuntos ou pacotes de práticas organizacionais são identificados como “sistemas das práticas HRM e de KM”. Caracterizamos, respectivamente, (i) firmas tradicionais na organização do trabalho; (ii) firmas usando práticas de gestão de pessoal com incentivos e (iii) firmas de aprendizagem, adicionando aos incentivos práticas de gerência do conhecimento. Correspondem aos modelos organizacionais teóricos, incluindo arquiteturas organizacionais modernas, baseadas em incentivos para desenvolver competências e conhecimento, sem deixar de lado firmas inspiradas em *tayloring*. Os resultados empíricos permitem concluir que os pacotes
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das práticas de HRM e de KM produzem significativo e positivo impacto no desempenho da inovação, quando mudanças marginais em práticas individuais dão pouco resultado. Além disso, a fim de confirmar tais complementariedades, concentramo-nos em quatro práticas específicas usadas, principalmente, por firmas: gerência da equipe, dos incentivos, do treinamento e do conhecimento. Empregamos novo procedimento, baseado no conceito de supermodularidade, para estudar a complementaridade e a substitutabilidade em casos onde práticas organizationais múltiplas afetam o desempenho inovativo. Este procedimento baseia-se na limitação múltipla da desigualdade. Nossos resultados sugerem que as firmas usam certas práticas de maneira comum e sistematicamente, que explicam sinergias existentes. O resultado confirma a noção de que a gerência do conhecimento é mais eficaz quando acompanhada pela organização da equipe e por incentivos conjuntos. Isto implica na construção de maior integração entre as teorias da agência e dos incentivos e as teorias baseadas em competências e em conhecimento.

Palavras-chave: gerência de conhecimento; recursos humanos; inovação; complementaridade; supermodularidade.

INTRODUCTION

Is it possible to understand technological innovation independently of human resources management and knowledge management practices? Do competencies and knowledge are substitutes or complements to incentives and motivations? Where is the place for the integration of incentives theories and competencies theories?

In order to respond to these questions, this paper examines the knowledge creation, sharing and transferring process in French manufacturing firms in an innovation perspective. Since employees, competencies and knowledge are an innovative firm’s major asset, we investigate arrangements capable of enhancing, capturing and utilizing knowledge within the firm. The aim of this paper is to study the complementarities between specific human resource management practices (henceforth HRM) and knowledge management (KM), and their impact on innovation.

Complementarity provides a way to capture the intuitive ideas of synergies and systems effects, i.e. “the whole is more than the
sum of the parts”. Complementarity between variables or strategies is achieved “if doing more of one thing increases the returns to doing more of another” (Milgrom and Roberts, 1995, p. 181). We thus have mutual reinforcement between these variables. Complementarity between a set of variables means that the marginal returns to one variable increases the level of any other variable. In the case of discrete decisions variables, the notion of complementarities requires to use the theoretical concept of supermodularity within the mathematical concept of lattices.

First, we study organizational diversity of manufacturing firms linked to theoretical organizational models. Three clusters or bundles of organizational practices are identified as “HRM and KM practices systems”. These three clusters characterized respectively (i) traditional firms at the work organization concerned; (ii) firms using incentives personnel practices and (iii) learning firms using, added to incentives, knowledge management practices. They correspond to theoretical organizational models including modern organizational forms without forgetting inspired tailoring firms, but show the important place of incentives to develop competencies and knowledge. We investigate the impact of organizational models on innovation performance compared to marginal changes in individual practices. Empirical results permit to conclude that HRM and KM practices form a coherent system of mutually reinforcing practices and act in favour of technological innovation. Second, in order to confirm these complementarities, we use a new testing procedure for complementarity and substitutability in case there are multiple organizational practices that affect innovative performance (Lokshin et al., 2004; Galia and Legros, 2006; Mohnen and Röller, 2005; Percival, 2005). This procedure is based on multiple inequality restriction. This testing methodology is applied to test the complementarities between four practices such as: team, incentives, training and knowledge management. Our results suggest that firms use some practices in a joint way and systematically, and account for synergies existing between these practices. The result supports the notion that knowledge management is more effective if accompanied by team organization and associated incentives. In other words, team work must be systematically associated with incentives and knowledge management in order to reach the maximum performance. It pleads in favour of the important interrelations and
couplings between specific HRM practices and knowledge management to enhance innovation performance. These results imply a more comprehensive integration between agency and incentives theories and theories based on competencies and knowledge.

This paper is organized as follows. Reviews the literature on HRM and KM practices complementarities and their impact on innovation performance. Introduces the testing method for complementarity. Describes the data and the variables. Introduces the Factor Analysis and Clustering method. Econometric specifications and main results are presented and discussed in conclusions.

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Knowledge based theory of the firm is developed in recent contributions in economic and management literature and describe approaches which organize knowledge creation and exploitation (Nonaka and Takeuchi, 1995; Tidd, 2000; OECD, 2000; Tomlinson, 2002; Foss and Mahnke, 2003). Competitive advantage depends upon the firm utilization of existing knowledge and its ability to generate new knowledge more efficiently. Competencies concerning knowledge management influence the spread and increased performance of information and communication technologies (ICT) and the way knowledge can be accessed and disseminated much more readily. In this paper, we pay attention to the fact that knowledge is based around solving new problems within teams, in an innovation perspective, which often require a multidisciplinary approach and adequate HRM practices (Foray and Lundvall, 1996; Foray, 2001). We describe the way firms and employees learn, work and communicate knowledge within and without the firms by using team, incentives and training procedures.

Employees, competencies and knowledge constitute a competitive advantage. Coordination and incentives mechanisms contribute to the efficiency of the creation and exploitation of knowledge. The firm can be presented as a competent team where a tacit organizational competence improve the productivity through selecting and allocating competent people (Eliasson, 2000). Therefore, human resource management practices are not only important but constituted one the most strategically relevant resources (Milgrom and Roberts, 1990, 1995; Baron and Kreps, 1999).

New types of incentives and procedures permitting an efficient knowledge creation and sharing, within teams, are required to en-
courage people in a knowledge-based economy. Stimulating creativity and sharing knowledge become essential and require appropriate HRM practices (Gupta and Singhal, 1993). Recent empirical evidence tend to prove that knowledge development and utilization can be facilitated by human resource practices (Leiponen, 2000a, 2000b; Laursen and Manhke, 2001; Laursen, 2002; Galia and Legros, 2004). At the individual level, increased delegation of responsibility and freedom for creativity may better allow for discovery and utilization of local and dispersed knowledge inside firms. Focusing on the interrelations and complementarities between specific HRM practices and knowledge management we identify in this paper these complementarities and synergetic effects, and the firms’ characteristics conducive to innovation.

The approach in terms of competencies has been developed in order to understand the internal design of the firm. Penrose (1959) first work presents the firm as a collection of resources associated with an administrative structure. The firm is characterized by one specific combination of resources. The competence is constituted by the set of knowledge characterizing the firm and being at the origin of its competitive advantage. The know-how and the capacities of reaction and adaptation complete the resources. Competencies are contained in the routines of the firm defined by Nelson and Winter (1982) as mechanical rules of behavior (rules of thumb). These routines allow the firm to face complexity and uncertainty.

Organizational competencies are determined by a hierarchy of routines. They are elemental organizational knowledge, their coordination and the decision procedure permitting to choose the right strategy. The organization, i.e. the firm (supporting the knowledge) is a “whole in terms of competencies more than the sum of the parts” (Penrose, 1959; Milgrom and Roberts, 1990, 1995; Foray and Mairesse, 1999). So, the firm is an organization working as a team and its efficacy is clearly superior to the sum of its constituting parts. In others words, the administrative structure of the firm is more than a collection of individuals.  

1 The resources are defined as tangibles and intangibles factors, and services extracting from these factors.

2 Carlsson and Eliasson (1994) define four types of competencies (selection capacity, organizational competence, technical competence, learning capacity) being complements at the level of the firm.
Knowledge development and utilization can be facilitated by human resource practices (Gupta and Singhal, 1993; Nonaka and Takeuchi, 1995; Leiponen, 2000a, 2000b, 2000c; Laursen and Mahnke, 2001; Laursen, 2002). Competitive advantage depends upon the firm utilization of existing knowledge and its ability to generate new knowledge more efficiently (Penrose, 1959; Nonaka and Takeuchi, 1995; Tidd, 2000; OECD, 2000). At the individual level, increased delegation of responsibility and freedom for creativity may better allow for discovery and utilization of local and dispersed knowledge in the organization.

Additionally, interdisciplinary team-work, regrouping employees with different characteristics, knowledge, expertise and skills, may be conducive to innovation (Gupta and Singhal, 1992; Milgrom and Roberts, 1990, 1995; Baron and Kreps, 1999). Team-based work can also facilitate cross-functional communication, enhance worker involvement, and develop or better utilize talent to serve strategic aspirations (Gupta and Singhal, 1993; Huselid, 1995). Autonomy in the job can be very effective in mobilizing personal knowledge as it helps organizational members to understand a firm’s business from a variety of perspectives. It provides coordination advantages when engineers and workers perform several tasks and therefore understand problems of colleague better. Among other things teams often bring together knowledge and skills which, before introduction of teams, existed separately resulting in “new combinations”. Moreover, team organization have to be coupled with specific procedures of incentives and reward devoted to the formulation of new ideas in order to motivate and facilitate creation and sharing of new knowledge within the firm.

Firm internal and external training contribute also to innovation performance. Firms upgrade skills and expertise of workers through on-the-job training, seminars, learning by doing to create firm specific human capital. When employees are concerned by the right (intrinsic or extrinsic)\(^3\) motivation, they may invest more in upgrading their skills if extensive problem-solving rights apply. Conversely, benefits from giving shop floor employees more prob-

\(^3\) Baron and Kreps (1999) defined intrinsic factors as whose associated with the work itself, frequently for the sake of personal satisfaction (work environment, quality of co-workers, ability and freedom for creativity to pursue research interests of greatest interest to the R&D personnel or researchers). Extrinsic factors are programs and inducements designed to encourage personnel (rewards, compensation, public and peers recognition).
lem-solving rights will likely depend positively on the level of training of such employees.

All such practices are likely complementary to various incentive-based reward and remuneration schemes (whether based on individual, team or firm performance, see Holmstrom and Milgrom, 1994) that reduce turnover. High powered incentives may be used to induce contributions through providing larger shares of quasi rents to employees. Thus, compensation, reward and career systems influence employees’ contribution.⁴

**Testing for complementarity: supermodularity of the innovation function**

Recent theory of the firm and HRM practices (quoted above) provides a way to capture the intuitive ideas of synergies and systems effects, *i.e.* “the whole is more than the sum of the parts”. Complementarity between variables or strategies is achieved “if doing more of one thing increases the returns to doing more of another” (Milgrom and Roberts, 1995, p. 181). We thus have mutual reinforcement between these variables, acting as a synergetic effect.

In a standard (differentiable) framework, complementarity between a set of variables means that the marginal returns to one variable increases the level of any other variable. Formally, the cross-partial derivatives of some payoff function (like profit or innovation) are positive. When the decisions variables are discrete, in the case of qualitative variables, the notion of complementarities requires that some order relations be put on the objects under consideration, formalized by the theoretical concept of supermodularity within the mathematical concept of lattices.⁵

The pioneer research in economics by Milgrom and Roberts (1990, 1995), using the theoretical concept of lattices and supermodularity (see Topkis, 1998), study the complementarity among a variety of decision variables, such as production, flexibility,

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⁴ Gupta and Singhal (1993) describe four dimensions (human resource planning, performance appraisal, reward system and career management) fostering innovation and creativity within the firm.

⁵ This research area started with the work of Samuelson (1974), Vienott (1989) and Topkis (1998). Specially, a lattice \((X,\preceq)\) is a set \((X)\) with a partial order \((\preceq)\) where each pair of elements \((x,y)\) has a least upper bound, noted \(x \cup y\), and a greatest lower bound, noted \(x \cap y\) (Topkis, 1998, p. 13). See also Amir (2004) for a theoretical survey dedicated to economic applications.
innovation, skills, training, incentive schemes and organizational decisions. Given complementary, a practice or a strategy is more likely to be adopted at a higher level if other practices are adopted at high level, too. This emerging important literature in organizational economics (complementarity and systemic effect between HRM practices) is also considered by Holmstrom and Milgrom (1994) and Ichniovski et al. (1997). Baron and Kreps (1998) promote consistent HRM (“best”) practices used in a system-like manner. For example, authors suggest that HRM policies that emphasize extensive and intensive training should be complemented by compensation, promotion, and recruitment policies that reduce turnover.

The empirical literature studying complementarities between various variables proposes three types of approaches: the correlation approach, the reduced form exclusion restriction approach and the productivity approach (see Athey and Stern, 1998).

The first approach tests the positive correlation between various variables conditional on a certain number of common explanatory variables. In other words, complementarity creates a force in favor of positive correlation (or clustering) between two variables, even after controlling for observable, exogenous characteristics. This insight, analyzed theoretically in Holmstrom and Milgrom (1994), Arora and Gambardella (1990), and Arora (1996), motivates the use of the correlation approach. Most of recent empirical papers about complementarity use this approach.6

The idea of the second approach is the following: a factor which as an effect on one variable will not be correlated with another variable unless the variables are complementary. As noted by Athey and Stern (1998) and discussed by Arora (1996) this approach does not provide a general solution for testing complementarity when there are more than two choices variables.

Finally, the third approach which we pursue here consists in modelling a measurement of firm’s objective function with a set of regressors, including the interaction effects or clusters between several variables, interpreted as parameters of complementarities. In this paper, we consider the innovation function as the firm’s objective

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6 A substantial benefit of the correlation approach is that it can be used even if only the choice variables are observed. Thus, availability of data on the objective function is not required. Studies which use this approach include Ichniovski, Shaw and Prennushi (1997); Colombo and Mosconi (1995); Laursen and Mahnke (2001); Galia and Legros (2004).
function. Ichniowski, Shaw and Prennushi (1997) provide the most convincing example of the application of this approach on HRM practices. Authors define and assume their different HRM “systems” (i.e. particular combinations of HRM practices) from the outset only in steel-finishing lines. Empirical evidence demonstrate that lines using incentive pay, teams, flexible job assignments, employment security and training achieve substantially higher productivity levels, than do lines with more traditional HRM approach. Furthermore, in different empirical studies the HRM “systems” emerge out of the empirical analysis (using clustering method). They all conclude that coherent high performance HRM “systems” have an economic and empirical positive effect on firm performance and innovation.

Following also this approach, Mohnen and Röller (2005) directly estimate the innovation function and investigate whether the innovation function is supermodular in the four policy action considered. Lokshin et al. (2004) study complementarity between practices for the case of three and four practices. On the one hand, they test for complementarity between product, process and organizational innovation and their impact on labour productivity. On the other hand, they discuss complementarity between four different types of R&D cooperation strategies. Percival (2005) estimate complementarities in the implementation of advanced manufacturing technologies in Canada. In this paper we test the supermodularity of the innovation function in four specific practices.

In the case of discrete decisions variables, the notion of complementarities requires to use the theoretical concept of supermodularity within the mathematical concept of lattices. We define complementarity in the objective function $f$ as follows (see for example Topkis, 1998, p. 43):

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7 Others studies on HRM practices using the productivity approach are Huselid (1995); Becker and Huselid (1998); Leiponen (2000a, 2000b); Laursen and Foss (2003); Lhuillery (2003); Galia and Legros (2005). They all conclude that coherent high performance HRM “systems” (i.e. particular combinations of HRM) have an economic and empirical positive effect on firm performance and innovation.


9 More precisely, authors use CIS1 survey data from four European countries and consider four types of obstacles that are affected by policies: (i) lack of appropriate sources of finance, (ii) lack of skilled personnel, (iii) lack of opportunities for cooperation with other firms and technological institutions, and (iv) legislation, norms regulation, standards and taxation.
A useful result for the empirical analysis below is that it suffices to check pairwise complementarities in case there are more than two dimensions in the lattice (Topkis, 1978). In other words, a function is supermodular over a subset of its arguments, if and only if all pairwise components in the subset satisfy the above definition.

In particular, we consider in this paper an innovation function $I$ of which the value is determined by the discrete practices $(p=1,...,n)$. Using the above definition of supermodularity and considering the first two practices we can write:

In our case, since the HRM and KM practices are of dichotomous nature (1 if firm use the practice considered; 0 otherwise), it represents a special case of this definition. Suppose there are two binary practices, the collection of possible combinations $D$ consists of four elements $D=\{(0,0),(0,1),(1,0),(1,1)\}$ as defined usually in binary order. Using the above definition of supermodularity implies that there is only one nontrivial inequality constrain $I(1,0)-I(1,1)<I(0,0)-I(0,1)$ or equivalently $I(1,1)+I(0,0)-I(1,0)-I(0,1)>0$. We can rewrite this inequality as $I(1,0)-I(0,0)<I(1,1)-I(0,1)$. The intuition from this last inequality is that using the first practice is more effective when the second practice is used.

We can illustrate our purpose with a simple example. Suppose a firm can use team-based work and incentive schemes (corresponding to ) or not at all (corresponding to ), as well as the mixed cases corresponding respectively to the only use of team and to the only use of incentives (corresponding respectively to and ). The above inequality constrain $I(1,0)-I(0,0)<I(1,1)-I(0,1)$ defining complementarity implies that using the first practice (team-based work) is more effective when the second practice (incentive schemes) is used. In other words, the impact of team-based work is higher whenever we have incentive schemes.

As we test in this paper for complementarity between the four following practices: team, incentives, training and knowledge management, we rewrite the associated inequality constrains. With four practices, $(x_1, x_2, x_3, x_4)$, the collection of possible combinations $D$ contains $2^4=16$ elements. Thus, the elements of $D$ are the following: $(0,0,0,0), (0,0,0,1), (0,0,1,0), (0,0,1,1),..., (1,1,1,1)$. The set $D$ is a lattice
as the elements are ordered as the component-wise order under the "max" operation. Using the above definition of supermodularity, and the fact that we only need to check pairwise complementarities, the number of nontrivial inequality constraints is equal to 
\[ 2^{k-2} \sum_{i=1}^{k-1} i \] 
where \( K \) is the number of practices. As we consider here \( K=4 \) practices, we have a total of 24 nontrivial inequality constraints.

More precisely, as we only need to check pairwise complementarities and we consider \( K=4 \) practices, we have 6 possible pairs of practices such as: \( x_1 \) and \( x_2 \), \( x_1 \) and \( x_3 \), \( x_1 \) and \( x_4 \), \( x_2 \) and \( x_3 \), \( x_2 \) and \( x_4 \), and finally \( x_3 \) and \( x_4 \). Then, we can write the constraints corresponding to complementarity between each pairs of practices. We thus have a total of 24 nontrivial inequality constraints as we said above.

Using the above definition of supermodularity we can write the 4 nontrivial inequality constraints concerning complementary between practices and in innovation function \( I \) as

\[
I(1,0, x_3, x_4) - I(1,1, x_3, x_4) \geq I(0,0, x_3, x_4) - I(0,1, x_3, x_4) \quad (3.1)
\]
where \( ( x_3, x_4) = \{ (0,0), (0,1) (1,0) (1,1) \} \)

or equivalently

\[
I(1,1,0,0)+I(0,0,0,0)-I(1,0,0,0)-I(0,1,0,0) = 0 \quad (3.2)
\]
\[
I(1,1,0,1)+I(0,0,0,1)-I(1,0,0,1)-I(0,1,0,1) = 0
\]
\[
I(1,1,1,0)+I(0,0,1,0)-I(1,0,1,0)-I(0,1,1,0) = 0
\]
\[
I(1,1,1,1)+I(0,0,1,1)-I(1,0,1,1)-I(0,1,1,1) = 0
\]

Similarly, the 4 nontrivial inequalities necessary to hold for practices \( x_1 \) and \( x_3 \) to be complementary are

\[
I(1, x_2, 0, x_4) - I(1, x_2, 1, x_4) \geq I(0, x_2, 0, x_4) - I(0, x_2, 1, x_4) \quad (3.3)
\]
where \( ( x_2, x_4) = \{ (0,0), (0,1) (1,0) (1,1) \} \)

The remaining 16 constraints corresponding to complementarity between practices \( x_1 \) and \( x_4 \), and \( x_3 \), \( x_2 \) and \( x_4 \), and finally \( x_3 \) and \( x_4 \) are analogous. Complementarity over all HRM and KM practices is given, whenever all the 24 inequality constraints are satisfied.

Previous research examining complementarity between more than two practices has however been limited to estimating the pair-wise
interaction effects (*i.e.* the first restriction of equation (3.2)),\textsuperscript{10} with the exception of Lokshin *et al.* (2004), Percival (2005), Mohnen and Röller (2005) and Galia and Legros (2006), ignoring that complementarity is only established if it is holds regardless of the others practices adopted (*i.e.* ignoring the last three restrictions of equation (3.2)).

This approach is problematic because it ignores terms and is prone to an omitted variable bias which affects all coefficients used in the complementarity test. Therefore, the proper complementarity or substitutability test requires consideration of the complete set of HRM and KM practices: testing a set of multiple linear inequality restrictions.

In order to test these inequality constraints, we need to estimate the innovation function $I$. Therefore, we include a set of state dummy variables denoted by $D$ as explanatory variables. As defined above, $D$ is the collection of possible combinations of the four HRM and KM practices. Using the convention of binary algebra, we define the 16 dummy variables constituted $D$. The estimated coefficients associated to these state dummy variables allow us to test for complementarities between the four HRM and KM practices.

Additionally, we include firm-level control variables such as: size, technological intensity, group membership and R&D dummies.

After estimating the innovation function $I$, we apply the statistical tests of versus with $R$ having rank $k$ in the standard linear model $y=Xb+e$ with one of the inequalities holding strictly (see Gouriéroux *et al.*, 1982). This can be viewed as a distance or Wald test that permit to test simultaneously the above 24 inequality constraints. We follow Kodde and Palm (1986) who provide lower and upper bound critical values for this test.\textsuperscript{11} The null hypothesis is accepted when values of the Wald test are below the lower bound. On the contrary, a rejection of the null hypothesis occur when values are above the upper bound. The test is inconclusive when values are between the two bounds.

We next turn to the data description and the empirical analysis, which will test for complementarity between HRM and KM practices.

\textsuperscript{10} Examples of this research include Ichniowski *et al.* (1997); Becker and Huselid (1998); Michie and Sheehan (1999); Leiponen (2000a, 2000b, 2000c); Caroli and Van Reenen (2001); Lhuillery (2003); Laursen and Foss (2003) and Galia and Legros (2005).

\textsuperscript{11} Critical values for significance levels are ranged in size from 0.25 to 0.01 and degrees of freedom from 1 to 40.
DATA

The data used for this study come from two French data sets. The first one is the “Compétences pour Innover” 1997 survey, over the period 1994 to 1996, carried out by SESSI.12 This is non-mandatory survey sampled 5,000 manufacturing firms with at least 20 employees. In order to grasp the competencies to innovate, the questionnaire is built on a multidisciplinary way (see François, 1998; Foray and Maïresse, 1999). Firms respond to 9 large class of competencies (C1 to C9) given 73 elementary competencies, considered as organizational practices. All elementary competencies are of dichotomous qualitative nature (1 if firm have the competence considered; 0 otherwise). Focusing on the internal organizational practices and human resources management practices (C7) dedicated to the production of knowledge (C4), intellectual property rights (C6) and technological innovation (C3), four large questions are specially investigated.

The second data set is the French second “Community Innovation Survey”, “L’Innovation Technologique dans l’Industrie” (CIS2), also carried out by SESSI over the period 1994 to 1996, results from a questionnaire sent to a representative sample of more than 5,000 manufacturing firms above 20 employees. This investigation belongs to the Community Survey13 on technological innovation (for a detailed description, see François and Favre, 1998). The firms answer primarily on the nature of the technological innovations (products/processes, firm/market), the supervision of these innovations (i.e. innovation projects), the internal and external sources (of R&D), the objectives of the technological innovation. It provides also information about the main sources of information to innovate, the cooperation to innovate and finally the obstacles to the projects of innovation. We know also general information such as size, sector of activity, technological intensity and group membership of the firms. Finally, the merger of these data sets provides a sample of 2750 firms.

Table 1 displays descriptive statistics of the 21 HRM and KM practices dedicated to innovation. In the first large questions C1 & C3 dedicated to innovation strategy and development practices, we noted the relative importance of the team-based organization

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12 The SESSI is the industrial statistics department of the French Ministry of Economics, Finances and Industry.
13 Survey CIS2 is based on the Oslo Manual drawn up by the OCDE, and revised in 1996.
structure (76.7% of firms) and the inventory of employees’ competencies (64.1%). This last practice permit the firms to have an inventory of fixtures of the knowledge and know-how incorporated in their employees. This team-based work and inventory are designed to acquire, refine, and reinforce employee skills and behaviors necessary to implement the firm’s innovativeness. Looking at the knowledge production practices (C4), autonomy is extensively used as a factor enhancing innovation (78.5%). Firms use largely incentives devoted to the formulation of new ideas (76.5%) in order to motivate and facilitate creation and sharing of new knowledge within the firm. Using also individual reward (53.7%) and accepting creative behaviors non-directly productive (58.8%), firms permit to theirs employees to enhance the originality and creativity of ideas. They organize a common pool of knowledge (64.3%) that allows to share knowledge and to communicate more easily around the projects of innovation.

Intellectual property rights strategy (C6) focuses on identifying strategic knowledge and know-how of the firm (53.1%). Firms identify and make people aware that their knowledge is strategic and confidential (53%). Doing so, firms inform employees about the confidentiality of their knowledge in order to avoid dispersion of information and communication. The HRM practices (C7) most used by firms is to assess, before hiring people, the ability to work in team (78.7%). Among all the 21 practices considered here, this practice is also the most used one. Firms consider and exploit training procedure as a strategic practice. Specially, firms make employee aware of the importance of demanding and choosing an appropriate training (63.1%). Additionally, half of firms (48.6%) assess the ability of employees to innovate. Thus, an efficient training policy is achieved when employees are directly concerned and involved in the choice of (their own) training programs, as they are the first concerned.

Innovating firms are those who introduced new technological products and/or processes during the period 1994-1996. Our final sample contains 62.7% of innovating firms. Innovating firms are more prone to adopt HRM and KM practices to innovate (column 2 in Table 1). The mean dotation of HRM and KM practices is about 11.2 (out of 21) for the full sample of firms, whereas for innovating firms is about 13.2 (this difference is statistically different at the 1% level). Paying more attention to these fact, we can see that innovat-
ing firms adopt a specific organization (composed of HRM and KM practices). They are structured around their projects of innovation (58.4%) and use extensively team-based work (89.7%). Team organization requires associated recruitments procedures assessing the ability to work in team (89%) and making an inventory of employees’ competencies (72%).

In an innovation perspective, autonomy (used by 86.5% of innovating firms), incentives (84.8%), individual evaluation (62.6%) and common pool of knowledge (72.3%) become essential to enhance creativity, originality and formulation of new ideas. Compared to others firms, innovating firms accept more easily creative but non-directly productive behaviors (68%), that permit to construct a trust relation between firms and employees. Moreover, in an innovation strategy, property rights mechanisms and specific knowledge management become a strategic competence (65.9%). Innovating firms identify more easily their strategic knowledge and know-how (66.1%) and associated people (61.7%) than firms in the full sample. They actively monitor the communication on strategic knowledge (51.7%). Training programs are found to be more extensively used by innovating firms (74.6%). They need more to hire highly qualified people (39.7%) and assess their ability to innovate (60.3%) via rigorous recruitments and selections protocols. Therefore, the evidence generally supports hypothesis stating that systems of HRM and KM practices vary with firm-types.

Correlation between HRM and KM practices for innovation permit to draw a first picture of the more used practices in combination.¹⁴ Not surprisingly, and in accordance to the evidence related above, firms using team-based work made at the same time an assessment of the ability to work in team, an inventory of employees’ competencies and permit them to demand and choose adequate training. Employees within teams benefit from specific incentive, autonomy and reward in order to promote originality, creativity and innovation. Moreover, team participants face an active and focused intellectual property right strategy that permit to identify strategic knowledge and associated employees. At the same time, team employees constitute a highly scientific qualification expertise coupled with desired high innovation ability. They are aware that their knowl-

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¹⁴ Detailed correlation statistics are available upon request.
### Table 1 – HRM and KM Practices for Innovation (21 variables; N=2750 firms) (% of manufacturing firms)

<table>
<thead>
<tr>
<th>C1 &amp; C3</th>
<th>Innovation Strategy and Development Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>INVENTORY</td>
<td>Inventory of employees’ competencies</td>
</tr>
<tr>
<td>PROJECTS</td>
<td>Film structured around projects of innovation</td>
</tr>
<tr>
<td>TEAM</td>
<td>Team-based on common work to innovate</td>
</tr>
<tr>
<td>MOBILITY</td>
<td>Support fluidity between departments to innovate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C4</th>
<th>Knowledge Production Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCENTIVES</td>
<td>Incentives to new ideas formulation</td>
</tr>
<tr>
<td>AUTONOMY</td>
<td>Leaves a certain autonomy level for innovation</td>
</tr>
<tr>
<td>IND/ EVAL</td>
<td>Individual evaluation of own originality and creativity</td>
</tr>
<tr>
<td>CREATIVE</td>
<td>Accept creative but non-directly productive behaviors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C5</th>
<th>Knowledge Production Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>REWARDS</td>
<td>Rewards original ideas when accepted</td>
</tr>
<tr>
<td>POOL KNOW</td>
<td>Conducts a common pool of knowledge</td>
</tr>
<tr>
<td>EVAL KNOW</td>
<td>Evaluation of collective knowledge production compared to rivals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C6</th>
<th>Intellectual Property Rights Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRAT KNOW</td>
<td>Identify strategic knowledge and know-how</td>
</tr>
<tr>
<td>IND/ KNOW</td>
<td>Identify individuals with strategic knowledge</td>
</tr>
<tr>
<td>AWARE KNOW</td>
<td>Makes people aware that their knowledge is strategic and confidential</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C7</th>
<th>Human Resources Management Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUALIFIED</td>
<td>Hiring highly scientifically qualified employees</td>
</tr>
<tr>
<td>ABILITY INNO</td>
<td>A sense of the ability to innovate</td>
</tr>
</tbody>
</table>

1 Frequency equality is accepted at the 1% level, all others are rejected. Figures in bold indicate higher value of frequency. Source: SESSI (1997)
edge forms a strategic and confidential advantage and finally they receive specific motivation schemes (wage and career incentives).

As we defined C4 as knowledge production practices (including eight practices), we note that all these practices are highly correlated. A common pool of knowledge permitting to create, enhance and share knowledge within the firm is constructed using adequate incentives, autonomy, reward, creative and originality behaviors as core practices. This entire knowledge oriented strategy is highly conditioned by the ability of employees to work in team and by training programs. Firms can’t achieve an efficient knowledge-based strategy dedicated to innovation without an appropriate and efficient training procedure. Therefore, training procedures is composed of selecting the bests employees, offer them an appropriate and “fit” training (that they demand and choose) in an innovation perspective.

Moreover, intellectual property rights strategy (C6) forms an entire homogeneous procedure including: identification of strategic knowledge and know-how and associated individuals and awareness of people that their knowledge is strategic and confidential. Monitoring the communication of this kind of knowledge and motivate specifically these employees permit to enhance the diffusion of existing knowledge and production of new one within the firm. Alternatively, these practices permit also to restrict diffusion of knowledge without the firm. This strategy is contiguous to the use of employees’ implication in training program. An efficient defense of intellectual property rights is achieved when employees are informed and aware of their specific possibilities and objectives concerning their own knowledge.

As we noted above, the mean dotation of HRM and KM practices is about 11.2 (out of 21) for the full sample of firms, whereas for innovating firms is about 13.2. When we look at firms’ size, we noted that large firms are more prone to adopt and use formal HRM and KM practices (since they declare a mean dotation of 14.2) than others. Mean dotations of medium high technology (MHT) and high technology firms (HT), respectively 13.4 and 14.4, tend to be higher than the mean dotation of others firms. Concerning the group membership, the mean dotations of french and foreign firms are respectively 12.4 and 13.4. These results tend to prove that large firms, high technological firms and firms belonging to a group are

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15 Detailed descriptive statistics are available upon request.
more prone to adopt and use formal HRM and KM practices than other firm are.

**Factor analysis and cluster analysis: three organizational models**

In this section, we seek to form clusters (or groups) of HRM and KM practices in order to study organizational diversity of manufacturing firms. These clusters are formed using the following criterion: their linear combination must explain as much as possible the variance of the responses to the HRM and KM practices. In other words, each cluster should contain firms which are similar regarding their HRM and KM practices, whereas clusters themselves should be as heterogeneous as possible. This cluster analysis is useful in order to reduce the number of variables used in the empirical regressions in the next section.

The HRM and KM practices variables resulting from the survey are of binary qualitative nature. Thus, we carry out a Factor Analysis (FA) and especially a Principal Component Analysis. The Principal Component Analysis is a descriptive method, which makes it possible to study the connections between qualitative variables. In the framework of the FA, the quality of the adjustment provided by the first factorial plan is satisfactory since this first two dimensional factor space restores approximately 37% of total inertia. The Catell’s criterion (called sometimes algorithm of the elbow) invites us to retain the first three factorial axis.

The Factor Analysis based on HRM and KM practices confirms the results obtained by the binary correlations. The first factorial axis gathers the organizational rules dedicated to the inventory of employees’ competencies, the use of project in a team-based work organization, the individual reward of creativity and originality as well as the construction of a common pool of knowledge. This common pool of knowledge requires specific motivation procedures for employees holding strategic knowledge. Assess the employees’ ability to innovate and permit them to demand and choose an ap-

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16 The algorithm of the FA is applied to the complete disjunctive table resulting from the table of condensed coding. We gave the state of active element to the 21 KM and HRM practices variables. Since the active questions have two modalities (1 or 0), no KM and HRM practices has *a priori* more importance than another.

17 The eigenvalues, rate of inertia and contribution to axis i’s variance are available upon request.
appropriate training are associated with the preceding practices. With regard to the second axis, we record the importance of a coherent knowledge management strategy, regrouping incentives to new ideas formulation, acceptance of creative behaviors, identification of know-how. Associated people with strategic knowledge are identified and are considered as highly scientific qualified employees. These KM practices are associated with making employees aware that their knowledge is strategic and confidential and finally, with monitoring the communication of this kind of knowledge. For the third axis, the practices regrouped are the assessment of employees’ ability to work in team, their individual participation to the knowledge production, and leaving us a certain autonomy level.

In Table 2, we find some evidence where HRM and KM practices form coherent strategic bundles considered as organizationals models. We identify three clusters or bundles\(^\text{18}\) of organizational practices as “HRM and KM practices systems” linked to theoretical organizational models. These three clusters characterized respectively (i) traditional firms at the work organization concerned; (ii) firms using incentives personnel practices and (iii) learning firms using, added to incentives, knowledge management practices. These clusters contain respectively 808, 926 and 1016 firms.

As specified in next Fig 1, these clusters correspond to theoretical organizational models including modern organizational forms without forgetting inspired tayloring firms, but show the important place of incentives to develop competencies and knowledge. Traditional firms correspond to hierarchy firms based on control and evaluation of employees. Firms using incentives practices are linked to agency and incentives theories where hierarchy and control are replaced by incentives and motivations. Finally, learning firms highlights the limits of agency and incentives theories, and are linked to evolutionary theories based on competencies and knowledge. This typology correspond to modern organizational forms without forgetting inspired tayloring firms, but show the important place of incentives to develop competencies and knowledge.

More precisely, traditional firms contains firms characterized by few HRM and KM practices dedicated to innovation. Moreover, half of firm leave a certain autonomy level for innovation, that constitute the most used practice in traditional firms. Organized in

\(^{18}\) We use the classical Ward’s minimum variance criterion.
Table 2 – Firms’ organizational models of HRM and KM practices for innovation (21 variables; N=2750 firms)

<table>
<thead>
<tr>
<th>C1 &amp; C3</th>
<th>Innovation Strategy and Development Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>INVENTORY</td>
<td>All firms</td>
</tr>
<tr>
<td>PROJECTS</td>
<td>64.15</td>
</tr>
<tr>
<td>TEAM</td>
<td>76.69</td>
</tr>
<tr>
<td>MOBILITY</td>
<td>53.52</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C4</th>
<th>Knowledge Production Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCENTIVES</td>
<td>All firms</td>
</tr>
<tr>
<td>AUTONOMY</td>
<td>78.51</td>
</tr>
<tr>
<td>INDIV EVAL</td>
<td>53.71</td>
</tr>
<tr>
<td>CREATIVE</td>
<td>58.84</td>
</tr>
<tr>
<td>REWARDS</td>
<td>46.55</td>
</tr>
<tr>
<td>POOL KNOW</td>
<td>64.33</td>
</tr>
<tr>
<td>EVAL KNOW</td>
<td>27.16</td>
</tr>
<tr>
<td>INDIV KNOW</td>
<td>20.84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C6</th>
<th>Intellectual Property Rights Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRAT KNOW</td>
<td>All firms</td>
</tr>
<tr>
<td>INDIV KNOW</td>
<td>53.16</td>
</tr>
<tr>
<td>AWARE KNOW</td>
<td>49.31</td>
</tr>
<tr>
<td>MONITOR</td>
<td>53.02</td>
</tr>
<tr>
<td>MOTIVATE</td>
<td>40.04</td>
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</table>

<table>
<thead>
<tr>
<th>C7</th>
<th>Human Resources Management Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUALIFIED</td>
<td>All firms</td>
</tr>
<tr>
<td>ABILITY INNO</td>
<td>27.78</td>
</tr>
<tr>
<td>ABILITY TEAM</td>
<td>48.62</td>
</tr>
<tr>
<td>TRAINING</td>
<td>78.69</td>
</tr>
<tr>
<td>Mean dotation of HRM and KM Practices</td>
<td>63.13</td>
</tr>
<tr>
<td>Number of firms</td>
<td>2750</td>
</tr>
</tbody>
</table>

1 Frequency equality between cluster and full sample is accepted at the 1% level, all others are rejected. Figures in bold indicates higher value of frequency. Source: SESSI (1997)

team, such firms select employees (regarding their ability to work together and their own competencies) and use incentive in order to new ideas formulation. All others practices are adopted by less than quarter of firms and the mean dotation of HRM and KM practices is about only four practice out of 21.

The mean dotation of HRM and KM practices in incentive firms is 12.3, that is more than 11.2 in the full sample. Incentive firms are
more likely to use autonomy and incentives in a team-based and employees’ competencies work structure. They focus on employees’ ability to work in team and adoption of an appropriate training strategy in order to enhance their innovative capacity. A common pool of knowledge is mostly conducted by these firms and is entangled in the importance of strategic and confidential knowledge properties.

Finally, learning firms gathers firms who adopt and use all the different HRM and KM practices equally and together. The mean dotation of HRM and KM practices in learning firms is 15.9 out of 21. Firms make more extensive use of team, inventory of employees’ competencies, assess the ability to work in team and to innovate, incentives, individual evaluation, autonomy, common pool of knowledge and training (almost 80-90% of firms use these practices individually). These features support hypothesis of core complementarities bundle of the firm. These HRM and KM practices form a coherent system of mutually reinforcing practices, since doing more of one practice increases the returns to doing more of another.

Learning firms also complement these practices by an adequate and extensive knowledge management strategy. They identify the strategic knowledge and know-how, and people holding this type of knowledge. They organize their knowledge production around the strategic and confidential properties of knowledge. Not surprisingly, a common pool of knowledge is conducted based on a teamwork structured around project of innovation. Firms pay a special attention to the monitoring of the knowledge communication and as a consequence, they motivate specially people concerned. In an innovation perspective these practices become essential to enhance
creativity, originality and formulation of new ideas and strategic knowledge. These practices act in favour of cross-functional communication and information, enhance personnel involvement, and develop or better utilize employees’ talent.

**Organizational Models: Complementarity System Effects**

In the following, we pay special attention to complementarities between HRM and KM practices and their impact on innovation performance. Different probit models explaining technological innovation are specified. It may be noted that the null hypothesis testing if the set of explanatory variables is equal to zero is strongly rejected by the likelihood ratio test for all our four specifications. When we regress innovation by “traditional” variables (size, technological intensity and group membership. We find some interesting results. Large firms are in general more prone to introduce technological innovation than small firms are. Being a high technological firm have highly significant and positive impact on the innovation probability. Group membership acts in favour of innovation. Moreover, firms belonging to a foreign group innovate more easily than french firms. These evidence are in accordance with many stylized facts.19

In order to test the impact of individuals HRM and KM practices, we estimate another model including all our 21 practices individually.20 We find also positive and significant effect of firms’ size. Moreover, high technological sectors and group membership become insignificant. Concerning the HRM and KM practices, we first noted that only 10 practices out of 21 are individually significant. Team-based organization (TEAM) around innovation projects (PROJECTS) and adequate internal alignment of HRM and KM practices (including specific recruitment assessing employees’ abilities (QUALIFIED and ABILITY TEAM) and acceptance of creative behaviors (CREATIVE)) have positive and large impact on innovation performance. Innovative capacities are also enhanced in developing an active knowledge management strategy (identify strategic knowledge and know-how (STRAT KNOW) awareness of strategic and confidential use of knowledge (AWARE KNOW) and related specific motivation procedures (MOTIVATE)).

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19 See Encaoua et al. (2000) and Kleinknecht and Mohnen (2001).

20 We do not include all these results in this paper, but they all are available upon request.
Surprisingly, two practices have significant and negative impact on innovation in this model. Firstly, support mobility of employees between departments (MOBILITY) reduces innovation capacity. Changing personnel attribution and role without total implication of employees concerned can be counterproductive in terms of creativity and innovativeness. Secondly, evaluation of the individual participation to the knowledge production (INDIV KNOW) restricts innovation capacities. When it occurs, an effective individual evaluation requires specific procedures and rules of control, and can reduce autonomy and trust relation among employees and firms. As a consequence, it can also annihilate creative and original ideas formulation, and reduce voluntary participation and communication among employees.

We find that being traditional firms or incentive firms have a significant and negative impact on the probability to innovate. Learning firms are strongly significant for firm’s ability to innovate. While individual HRM and KM practices have some positive impact on innovation HRM and KM practices organizational “systems” or clusters are significantly more conducive to innovation than individual practices. We take this as evidence of complementarities between HRM and KM practices in this analysis.

Furthermore, we can conclude that learning firms are more prone to innovate compared to others firms. Complementarities between team-work (TEAM) and innovation projects organization (PROJECTS), specific recruitment (based on high qualifications (QUALIFIED), employees’ competencies (INVENTORY), ability to innovate (ABILITY INNO) and to work in team (ABILITY TEAM)), incentives (INCENTIVES), autonomy (AUTONOMY), individual evaluation (INDIV EVAL) and training (TRAINING) exist and are largely efficient in an innovation perspective.

These practices are complemented efficiently by adequate and extensive knowledge management and intellectual property rights strategy including constitution of a common pool of strategic and confidential knowledge (POOL KNOW and AWARE KNOW) and specific motivation of people concerned (MONITOR and MOTIVATE). Identification of the strategic knowledge and know-how and people holding this type of knowledge (STRAT KNOW and INDIV KNOW) imply a monitoring of the communication (MONITOR) and act as a complementary practice.
These evidence shows that the effect of the individual HRM and KM practices in models without the HRM and KM clusters disappear once the HRM and KM clusters are also included. In other words, the systems of HRM and KM practices determine innovation performance, while marginal changes in individual practices have little effect.

Then, in an innovation perspective, all these practices become essential to perform and enhance creativity and originality. HRM and KM practices are found to form a system of interdependent practices conducive to technological innovation. These results add one more piece of evidence stating that HRM and KM practices form a coherent system of mutually reinforcing practices and act in favour of technological innovation.

These results have important implications for managerial practices and advancing research related to knowledge management strategies, human resource system design, and complementarity effects between HRM practices. They imply to construct a more comprehensive integration between agency and incentives theories and theories based on competencies and knowledge. An important result is that competencies and knowledge practices complements, and not substitutes, incentives and motivations schemes.

**FOUR SPECIFIC PRACTICES: TEAM, INCENTIVES, TRAINING AND KNOWLEDGE MANAGEMENT**

As regard on evidence above, we focus now on four specific practices mainly used by firms: teams-based or common work; motivate specifically (wage, career); demand and choose an adequate training; and awareness that knowledge is strategic and confidential.

We noted the relative importance of the team-based organization structure (TEAM, 76.7% of firms). This team-based work is designed to acquire, refine, and reinforce employee skills and behaviors necessary to implement the firm’s innovativeness. Specific motivation procedures (wage, career) are dedicated to employees that holds strategic knowledge (MOTIVATE, 40.2%). These incentives are devoted to motivate and to facilitate creation and sharing new knowledge within the firm. Using individual reward, firms permit to theirs employees to enhance originality and creativity of ideas. Moreover, the use of team-based work can allow to share knowledge and to communicate more easily around the projects of
innovation. Additionally, firms identify and make people aware that their knowledge is strategic and confidential (AWARE KNOW, 53%). Doing so, firms inform employees about the confidentiality of their knowledge in order to avoid dispersion of information and communication. Finally, firms consider and exploit training procedure as a strategic practice. Specially, firms permits employee to demand and choose an appropriate training (TRAINING, 63.1%).

Innovating firms are those who introduced new technological products and/or processes during the period 1994-1996. Our final sample contains 62.7% of innovating firms. We find that innovating firms are more prone to adopt HRM and KM practices in order to innovate. The mean dotation of HRM and KM practices is about 2.3 for the full sample of firms, whereas for innovating firms is about 2.8 (this difference is statistically different at the 1% level). Paying more attention to these fact, we can see that innovating firms seem to adopt a specific organization (composed of HRM and KM practices). They use extensively team-based work (89.7%). Moreover, compared to the full sample and to the non-innovating firms, innovating firms use more intensively associated motivation and incentive procedures (50.6%). In an innovation perspective, training programs are found to be more extensively used by innovating firms (74.6%). They actively involve employees in the strategic and confidential nature of knowledge (65.9%) since it become essential to keep creativity, originality and formulation of new ideas within the firm.

Correlation between the four HRM and KM practices for innovation are reported. We can draw a first picture of the more used practices in combination. Not surprisingly, and in accordance to the evidence related above, firms using team-based work permit at the same time to theirs employees to demand and choose adequate training. Moreover, team-based work is associated to strategic and confidential nature of knowledge embedded in team members. Therefore, employees within teams benefit from specific incentive in order to promote originality, creativity and innovation. At the same time, they are aware that their knowledge forms a strategic and confidential advantage and they receive specific motivation schemes (wage and career incentives).

The distribution of firms by size takes the standard classification used by the SESSI. We use also three categories of size (small firms (SF) from 20 to 99 employees, medium-sized firms (MF) from
100 to 499 employees and large firms (LF) of 500 employees and more) in order to widen the traditional contrast between small and large firms. In the full sample, 22% are large firms (LF), 26% are medium firms and 51% are small ones. Among innovating firms, one out of three is a large firm (LF). We observe the same proportion for the medium-sized firms (MF). Innovating small firms (SF) account for 38.7% of our sample.

Sectorial effects (line of business) are taken into account by technological intensity. The technological intensity of firms, used by the SESSI, is a typology carried out by the OECD in 1994. Four groups were formed: sectors of high technological intensity (HT), medium high technology (MHT), medium low technology (MLT) and low technology (LT). It is about a gathering of the industrial sectors according to direct and indirect intensity\(^{21}\) of R&D in the production, weighted by the 10 principal Member States. The full sample contains four out of ten low technology firms (LT), 35% of medium low technology firms (MLT), 18% medium high technology firms (MHT) and finally 7% of high technology firms (HT). A third of innovating firms belongs to the group of low technology (LT), 37% remains for the group of medium low technology (MLT). The group of medium high technology (MHT) accounts for 22.3%. High technology (HT) represents one firm out of ten.

Additionally, we use group membership information. Independent firms represents 44% of our sample, 31% belongs to a french group and 23% to a foreign group. Among innovating firms, distribution acts in favour of foreign group (30%) and french group (36%). Independent innovating firms are less (33%) than in the full sample (44%). Therefore, innovating firms tend to be larger, more technology oriented firms and belonging to a group than others firms are.

Finally, we also include R&D variables dedicated to innovative activities: internal R&D and external R&D. Internal R&D relates to 44% of firms. However, two firms out of ten sub-contracts R&D (external R&D, including with another firm of the group). Among innovating firms, six firms out of ten and 26% of them are engaged respectively in internal R&D and in external R&D.

\(^{21}\) After measurement of the intensities by sectors, 4 groups were formed: High Technology (intensity>8.5%), Medium High Technology (2.6%<intensity<4.5%), Medium Low Technology (1%<intensity<2.6%) and Low Technology (intensity<1%). To obtain the connection between the groups of technological intensity and NAF level 114 French nomenclature, refer to François (1998, pp. 154-155).
As we noted above, the mean dotation of HRM and KM practices is about 2.33 (out of 4) for the full sample of firms, whereas for innovating firms is about 2.81. When we look at firms’ size, we noted that large firms are more prone to adopt and use formal HRM and KM practices than others since they declare a mean dotation of 3.07. Mean dotations of medium high technology (MHT) and high technology firms (HT), respectively 2.80 and 3.06, tend to be higher than the mean dotation of others firms. Concerning the group membership, the mean dotations of french and foreign firms are respectively 2.63 and 2.88. Finally, we can note that firms engaged in internal and external R&D are more prone to use HRM and KM practices than others, where the mean dotation are respectively 2.93 and 3.00.

However, we can note the relative importance of procedure avoiding knowledge disclosure (AWARE KNOW) and schemes motivating employees (MOTIVATE) during the externalization of R&D. Specially, 78% of firms doing internal R&D use this knowledge management procedure, since they are 83% among firms doing external R&D. Moreover, 71% of firms engaged in internal R&D use specific motivation schemes, whereas 73% of firms doing external R&D are concerned.

To sum up, we find statistical differences between firms’ characteristics such as: (i) large firms use more appropriate HRM and knowledge management procedures permitting to create and exploit knowledge, than small firms do; (ii) high technological firms pay more attention to HRM and KM practices than others firms; (iii) firm belonging to a group are more prone to adopt an adequate knowledge management strategy and related HRM than others firms are; (iv) firms engaged in external R&D use more intensively knowledge confidentiality and specific motivation schemes than firms engaged in internal R&D; and (v) innovative firms use more intensively team work, specific incentives, training program and knowledge management than the sample mean.

These results tend to prove that large firms, high technological firms, firms belonging to a group and firms engaged in R&D are more prone to adopt and use formal HRM and KM practices than other firm are.

One way to test for complementarity is to test whether the practices are correlated. For instance, if practice (TEAM) occurs more often together with practice (MOTIVATE), rather than sepa-
rately, we may interpret this in favor of complementarity between the two practices.

In terms of pairwise complementarity, we can infer some evidence in favor of complementarity. For example, training (practice $x_3$, TRAINING) and knowledge awareness (practice $x_4$, AWARE KNOW) appear complementary since the occurrence of (0000) plus (0011) is more frequent than (0001) plus (0010). Furthermore, when firms use team and specific motivation schemes together (practices $x_1$, TEAM and $x_2$, MOTIVATE), we can see that (1111) plus (1100) occurs more often than (1101) plus (1110). Finally, the remaining two constraints for training ($x_3$) and knowledge awareness ($x_4$) are also met. These four constraints hold for the full sample, as well as for both sub-samples i.e. innovating firms and non-innovating firms. Therefore, these descriptive evidence act in favor of pairwise complementarity of training ($x_3$) and knowledge awareness ($x_4$).

In order to check all the other constraints for all other practice pairs we have to consider a large number of possible counts (20 constraints). As this checking is tedious, yet we can conclude that there is important descriptive evidence in favor of complementarity for other obstacle pairs as well. However, concluding from this on supermodularity of the innovation function can be premature. These descriptive statistics can only be considered as suggestive evidence of complementarity. They do not provide an effective test of complementarity, since they do not control for any other variables. Therefore, in the following we turn to a more systematic method by using an econometric approach.

**Complementarity Evidence: Testing for Supermodularity**

In order to pay special attention to innovation performance, we estimate probit models explaining the probability to innovate.

Regresses probability to innovate by “traditional” variables (size, technological intensity and group membership). Large firms are in general more prone to introduce technological innovation than small firms are. Being a high technological firm have highly significant and positive impact on the innovation probability. Group membership acts in favour of innovation. Moreover, firms belonging to a foreign group innovate more easily than french firms. As we said above, these evidence are in accordance with many stylized facts.
In order to test the impact of individuals HRM and KM practices, we estimate including all our four practices individually. We find also positive and significant effect of firms’ size. Moreover, high technological sectors and group membership become insignificant. Concerning the HRM and KM practices, we first noted that three practices out of four are individually significant. Team-based organization (TEAM), specific motivation schemes (MOTIVATE) and awareness of strategic and confidential use of knowledge (AWARE KNOW) have positive and significant impact on innovation. Nevertheless, appropriate training programs (TRAINING) have an insignificant impact on the probability to innovate.

Additionally to control variables, we introduce the set of state dummy variables in order to estimate their impact on innovation. We find that several practice states are not significant in the probability to innovate. Among the practice states being significant, a majority of them have a negative impact on innovation. However, this econometric estimation display evidence of firms using all the four HRM and KM practices jointly are more prone to innovate. The extreme practice state (1,1,1,1), where one is everywhere, induce the highest propensity to innovate. Furthermore, the practice state (1,0,1,1) have a significant and positive impact on the probability to innovate. In others words, firms using simultaneously team-based organization (TEAM), appropriate training programs (TRAINING) and confidential use of knowledge (AWARE KNOW) have a higher probability to innovate.

It is important to note that these individual significance and signs of the coefficients on the practice states do not directly provide a test whether the innovation function is supermodular or submodular for two reasons. First, supermodularity involves to test linear constraints of several coefficients. Second, supermodularity requires to test the joint distribution of several of these linear constraints. Therefore, it can be possible that all coefficients are statistically insignificant, even though the joint hypothesis for supermodularity is accepted.

In the first step the model is estimated three times, once unconstrained, once imposing greater or equal restrictions and once imposing less or equal restrictions. In the second step, the constrained model that produced the highest log-likelihood value in the first step is tested against the equality restricted alternative using the

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22 The model for which the imposition of the inequality restrictions are least objectionable.
LR test. We compare, in the first step, the log-likelihood value of the unconstrained model with the constrained log-likelihood values. This suggests to test for substitutability in case of team & motivation schemes, motivation schemes & training, and training & knowledge management. Complementarity is tested in the cases of team & training, team & knowledge management, and motivation schemes & knowledge management.

The log-likelihood ratio tests show, in the second step, that the null hypothesis of no substitutability cannot be rejected for the practices team & motivation schemes, motivation schemes & training, and training & knowledge management. These results occur because the corresponding LR test statistics are less than the tabulated value. Test of complementarity relationship between the practices team & training, team & knowledge management, and motivation schemes & knowledge management against the null of no complementarity effectively establishes them as complements. For example, result does reveal a complementary relationship between team & training: the LR test against the null of no complementarity is rejected, the value 12.525 being greater than the critical upper bound value 12.483.

The result supports the notion that knowledge management is more effective if accompanied by team organization and associated incentive schemes. Then knowledge management have greater impact on innovation performance when accompanied by necessary changes in organizational practices such as team implementation and specific motivation schemes (wage, career). In other words, team work must be systematically associated with incentives and knowledge management in order to reach the maximum performance.

**Conclusion**

This paper permits to map out a more comprehensive structure and strategy of the firms in the knowledge-based economy. In an innovation perspective, we investigate arrangements capable of enhancing, capturing and utilizing knowledge within French manufacturing firms. This paper aims at studying the complementarities between HRM and KM practices, and their impact on innovation at the empirical.

First, organizational diversity of the firms is showed since we identify three clusters or bundles of organizational practices as
“HRM and KM practices systems”. These three clusters characterized respectively (i) traditional firms at the work organization concerned; (ii) firms using incentives personnel practices and (iii) learning firms using, added to incentives, knowledge management practices. These three clusters correspond to theoretical organizational models. Traditional firms correspond to hierarchy firms based on control and evaluation of employees. Firms using incentives practices are linked to agency and incentives theories where hierarchy and control are replaced by incentives and motivations. Finally, learning firms highlights the limits of agency and incentives theories, and are linked to evolutionary theories based on competencies and knowledge. Results permit to conclude that HRM and KM practices bundles have significant and positive impact on innovation performance, while marginal changes in individual practices have little effect. Empirical evidence confirms that complementarities between HRM and KM practices exist such as these components practices reinforce each others. This demonstrate that these practices act as a coherent system, rather than individual components, linked to the firm’s types and knowledge management strategies.\(^{23}\)

Second, focusing on four specific practices: team, incentives, training and knowledge management; we use a new testing procedure, based on the supermodularity concept, for complementarity and substitutability in case of multiple organizational practices. This procedure is based on multiple inequality restriction of the innovation function.

The result supports the notion that knowledge management is more effective if accompanied by team organization and associated incentives. An important result is that competencies and knowledge practices complements, and not substitutes, incentives and motivations schemes. It pleads in favour of the important interrelations and couplings between knowledge management and specific HRM practices. Then, in an innovation perspective these practices become essential to perform and enhance creativity and originality. Knowledge management thus implies a deep organizational renewal of the firms rather than a management fashion effect.

These empirical results imply to construct a more comprehensive integration between agency and incentives theories and theories based on competencies and knowledge. One theoretical inves-

\(^{23}\) For see more tables and appendix in http://www.dime-eu.org/node/274.
tigation way could be the study of the impact of practices implementation costs within firms. This model can permit to explain the intensive use of practices in some industry sectors where as some firms maintains the use of traditional practices.

REFERENCES


